Effect of feeding Zilpaterol hydrochloride for 20 days to calf-fed Holstein steers with a 3
or 10 day withdrawal period antemortem on carcass characteristics and tenderness

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ABSTRACT

Effect of feeding Zilpaterol hydrochloride for 20 days to calf-fed Holstein steers with a 3 or 10 day withdrawal period antemortem on carcass characteristics and tenderness.

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The effect of feeding Zilpaterol hydrochloride (ZH) with a 3 or 10 d withdrawal (WD) period to calf-fed Holstein steers (N=2993) on carcass characteristics and tenderness were evaluated in a feed lot experiment. Cattle were fed 0 or 8.3 mg/kg of ZH for the final 20 d of the feeding period, each treatment level was assigned a WD period of either 3 or 10 d. Treatment groups consisted of Control 3 d WD (C3) and 10 d WD (C10), and ZH fed 3 day WD (Z3) and 10 d WD (Z10). Cattle were slaughtered at a commercial facility, carcasses chilled for at least 40 hours and carcass characteristics evaluated by trained personnel. Loins (n=60) were randomly selected from each treatment group for Warner Bratzler Shear (WBS) analysis. Rib-eye area (REA) increased 3.8 cm² for ZH fed 3 day WD cattle ($P<0.01$) when compared to control, and 5.4 cm² for ZH fed 10 day withdrawal cattle ($P<0.01$) when compared to control. There was no significant difference in REA between ZH fed 3 and 10 d WD periods ($P>0.05$). A trend was observed for ZH fed 10 d WD cattle to have an increased hot carcass weight when compared to control ($P=0.0589$), while there was no significant difference for cattle fed ZH with a 3 day WD ($P=0.3763$) comparatively. There was no difference in ZH fed cattle when compared to control on; kidney pelvic and heart fat %, adjusted preliminary yield grade, calculated yield grade, marbling score, or lean and bone maturity ($P>0.05$). There was an increase in WBS for ZH fed cattle when compared to control for Choice 7 d

and 14 d aged steaks for both WD periods. Choice Z10 steaks aged 21 d showed an increase in WBS ($P<0.05$) while the Z3 had no effect. Select Z3 7 d aged steaks had higher WBS when compared to control while Z10 had no effect. Oppositely, the Select Z10 14 d aged steaks had increased WBS while the Z3 had no effect. There was no difference in Select 21 d aged steaks. There was no difference in WBS between the Z3 and Z10 for any of the aging periods. Feeding Zilpaterol hydrochloride for 20 d increased carcass leanness while having little effect on carcass fat of calf-fed Holstein steers. There was no difference observed between 3 d and 10 d WD period. Zilpaterol hydrochloride treatment decreased steak tenderness, although as aging progressed there little to no difference between steaks from ZH fed and control cattle.

Key Words: Beef, Zilpaterol, Tenderness

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Thesis - Review of Literature

Introduction

U.S. consumers are looking for healthy, safe, and low cost meat items to put on the dinner table, although the definition of healthy, safe, and low cost seems to be changing every day. This has put pressure on animal agriculture and the meat industry to continue to provide the items that the consumer is looking for, while preserving the humane treatment and safety of the livestock it depends upon (Dunshea et al., 2005). Growth promoting technologies that the industry uses have come under great scrutiny because the consumer does not understand the technologies purpose. It is the industry's responsibility to prove to the consumer that the specific technologies used are safe and beneficial.

The beef industry has utilized technologies to produce cattle that grow more efficiently, meanwhile consuming less feed. The technologies used are commonly referred to as metabolic modifiers. In an in-depth review of the literature regarding the effects of metabolic modifiers on beef and pigs conducted by Dikeman (2007), metabolic modifiers were defined "as compounds that are either fed, injected, or implanted in animals to improve rate of gain, improve feed efficiency, increase dressing percent, increase carcass meat yield percentage, improve visual meat quality, extend shelf-life, improve meat's nutritional profile, or improve meat palatability." All metabolic modifiers utilize the animal's natural metabolic systems and signal them to favor growth and development of lean and/or fat tissue.

The cattle industry uses metabolic modifiers to increase productivity. Examples include somatotropins, anabolic steroidal hormones and β -adrenergic agonists (Dunshea

et al., 2005). While these modifiers have specific effects on lean and fat they work through different pathways. The steroidal implants are anabolic steroids, estrogen (E2), progesterone, testosterone, and trenbolone acetate (TBA), a synthetic anabolic steroid with 10 times the effect of natural testosterone (Dikemann, 2007). The effect to an animal's carcass with most steroidal implants is an overall increase of both lean and fat. While β -adrenergic agonists, also referred to as phenethanolamines (Mersmann, 1998), work similarly to epinephrine, activating specific receptors throughout all tissues, preparing animals for any situation that may require high amounts of energy. There are many different types of β -adrenergic agonists, a few of which have been approved to be fed to calf-fed Holstein steers.

Calf-Fed Holstein Steers

The effects of feeding β -adrenergic agonists to beef cattle have been studied for many years. Although, their effects on calf-fed Holstein steers is a growing area of interest because there are more calf-fed Holstein steers being fed in the United States, with a majority in the desert southwest (Eng, 2007). Eng (2007) suggests that there are many advantages to producing calf-fed Holstein steers for the beef industry in the desert southwest. The Holstein breed is more capable of enduring high temperatures than low temperatures. Eng (2007) went on to discuss that Holsteins are very consistent in growth and development because most Holsteins are closely related, having little variation between steers and because of this, Holsteins also have consistent feed to gain conversion. Another advantage to feeding calf-fed Holstein steers reported by Duff and McMurphy (2007) is that Holstein calves have less transportation cost to the feedlot. Calf-fed Holstein steers are bought and transported at lighter weights than traditional

stocker cattle, approximately 275 pounds (125 kg), which equates to a cost of transportation approximately one third the cost for a beef steer. However, Duff and McMurphy (2007) reported various disadvantages. Holsteins have a larger frame size than traditional beef cattle, requiring more space in the feeding pens, in addition to consuming more water than beef cattle, causing the pens to be more muddy and possibly leading to an increase in feet and leg problems. The authors also reported that Holstein steers are very curious and playful causing Holstein steers to have more problems with hardware disease as well as having issues with aggression. The Holstein breed also requires approximately 20% more energy for growth than beef cattle; hence the cattle eat more, resulting in a larger amount of feces (Eng, 2007).

The United States dairy cow herd is estimated at 9.2 million head including 1.8 million head in California (NASS, 2010). Milking dairy cattle have one calf per year in order to stay in milk production. This equates to approximately 900,000 male Holstein calves from California that will first enter a calf ranch, and ultimately reach a feedlot or veal operation. Holstein calves are weaned from their mothers immediately following the calves first feeding of colostrum. The calves are then placed into calf hutches where they are provided a milk replacer until 1-2 weeks of age. Once the calves have become accustomed to nursing in the calf hutch, calves are transported to a ranch that specializes in feeding calves and preparing them for the feed lot (Eng, 2007). At the calf ranch, the cattle will slowly be weaned off of the milk replacer, eventually transitioned onto a total mixed ration (TMR) at 4-5 months of age (MOA). The Holstein calves are eventually sold to the feedlot operation at approximately 6 MOA (Maas and Robinson, 2007). Calf-fed Holstein steers stay in the feedlot about twice as long as beef cattle. Traditionally, the

value of the male calves from the dairy industry have been low, although recently the price for a 300 pound steer has increased to around \$400.00 (Eng, 2007). Holstein steers first enter the feedlot at about 300 pounds and are sent to market at approximately 1300 pounds (590 kg). The steers are fed a high energy diet for approximately 365 days in order to get them to the required market weight (Duff and McMurphy, 2007).

Adrenergic Agonists

Epinephrine and norepinephrine are the two major circulating endogenous adrenergic agonists (AA) in mammals (Mersmann, 1998). Epinephrine is responsible for the flight or fight mechanism; its main purpose is to rapidly make energy available for metabolism in a high energy requiring situation (Stipanuk, 2006). It also helps to maintain energy homeostasis in low energy situations such as fasting or starvation. The AA response has been shown to include: hydrolysis of lipids into free fatty acids, breaking down stored glycogen into glucose, vascular dilation and constriction, increased heart rate, increased respiration rate, and the suppression of immune and inflammatory response (Stipanuk, 2006; Verhoeckx et al., 2005).

The physiological response in mammals to adrenergic agonists occurs when the intracellular receptor is activated. The adrenergic agonist's receptor is a G-protein coupled receptor located on the cell membrane. Upon binding of the adrenergic agonist to the adrenergic receptor (AR), a signal is transmitted through the cell wall and into the cell; this allows the receptor to react with guanosine triphosphate (GTP) binding protein of the G-protein complex. The G-protein will shift, activating adenylate cyclase. Adenylate cyclase catalyses the synthesis of cyclic adenosine monophosphate (cAMP),

which then allows for the phosphorylation of protein kinase A (PKA). PKA is found in many different tissue types and when phosphorylation occurs it is responsible for triggering the metabolism of glucose, insulin, amino acids, and glycogen (Stipanuk, 2006).

There are two primary types of adrenergic receptors (AR): Alpha (α) and Beta (β). The AR are further divided into sub-types: two α -adrenergic receptor (α_1 and α_2 subtypes) and three β -adrenergic receptor (β_1 , β_2 , and β_3 subtypes) (Mersmann, 1998). Multiple AA's have been identified that bind to specific receptors which aid in improving cattle performance and efficiency. The β -adrenergic receptor is present on bovine skeletal muscle in both fetal and adult beef cattle (Bridge et al., 1998). One of the receptors targeted in animal production is the β_2 -adrenergic receptor (BAR) which is found in high concentrations in skeletal muscle and adipose tissue (Sillence and Matthews, 1994).

The livestock production industry has used orally administered exogenous β_1 and β_2 -adrenergic agonists (BAA) to increase muscling and decrease fat for over ten years. The first BAA approved by the FDA to be fed to pigs was Ractopamine hydrochloride (RH), and since its approval in 1999 it has also been approved for the use with cattle and turkeys. Another BAA approved by the FDA to be fed to cattle was Zilpaterol Hydrochloride (ZH), approved in 2006 (Avendaño-Reyes et al., 2006). β -adrenergic agonists are referred to as metabolic modifiers or nutrient repartitioning agents (Verhoeckx et al., 2005). The BAAs activity is similar to epinephrine but are more specific to the β -adrenergic receptor. These compounds increase lean deposition by increasing the synthesis of protein, proteogenesis, and decreasing the breakdown of protein, proteolysis. β -adrenergic agonists also decrease the amount of fat by increasing

lipolysis and decreasing lipogenesis (Mersmann, 1998). As BAA's are circulating throughout the blood stream, they are removed and stored by the liver until it has the ability to be metabolized. Some BAA's can be stored in the liver for days (ZH) or even weeks (Clenbuterol hydrochloride) at a time before the liver is able to breakdown the BAA. Zilpaterol hydrochloride for example, has a mandatory withdrawal period of 3 days antemortem because of the concern of eating liver contaminated with BAA. Health problems have been reported with people consuming livers from cattle illegally fed the BAA Clenbuterol hydrochloride (CH) causing adverse health effects such as tremors, headaches, and dizziness (Sauer et al., 1999). In Mexico, consumers that ate liver from CH fed cattle without the proper withdrawal period had acute toxicity. This indicated misuse of CH because the withdrawal time was not being followed and therefore the BAA was removed from the market (Avendaño-Reyes et al., 2006).

Live Animal Effects

The physiological response to oral administration of BAA in beef animals is observed with an improvement in performance and a heavier muscled carcass. In a study conducted by Avendaño-Reyes et al. (2006) testing the effect of RH and ZH on performance, an increase in average daily gain (ADG) was observed for both BAAs, while a reduction in feed intake (DMI) was observed for only RH fed cattle. Because of the increase in ADG, there was an improvement in the gain to feed ratio (G:F). Similar effects for feeding ZH were reported by Vasconcelos et al. (2008) in beef cattle. Additionally, Beckett et al. (2009) reported a reduction in DMI for calf-fed Holstein steers fed ZH and similar effects on ADG and G:F. In a recent study conducted by Walker and Drouillard (2010), it was suggested that adrenergic agonists may affect the

microbial flora in the rumen. Ractopamine hydrochloride had an effect on not only the mammalian tissue, but also the ruminal metabolism of nutrients. The study also suggests that altering the diet by supplementing more protein in the diet actually increased the effects of RH. While evaluating the effects to the live animals are important for animal agriculture, it is also important to understand exactly what physiological changes to the carcass are occurring with the administration of BAA's.

Carcass Effects

Effects on carcass characteristics from cattle fed ZH and RH include increased rib eye area (REA), increased hot carcass weight (HCW), increased dressing percent (DP), reduced yield grade, and a reduction in tenderness (Beckett et al., 2009; Holmer et al., 2009; Vogel et al., 2005).

The feeding of BAA's are effective at increasing carcass muscling and reducing yield grade. In an experiment on feeding ZH for 0, 20, 30, or 40 days to calf-fed Holstein steers, Beckett et al. (2009) observed an increase in REA from cattle fed ZH for 20-40 days when compared to control. The author expressed that this was particularly important for calf-fed Holstein steers due to Holsteins tendency to have smaller REAs compare to commercial beef cattle. The feeding of ZH resulted in a decrease in cattle with small REA ($<71 \text{ cm}^2$). A decrease in USDA yield grade was also reported with increases in yield grade 1 and 2 carcasses and a decrease in yield grade 3 and 4 carcasses. Cattle fed ZH had increased live weights. Additionally when compared to the carcass weight gain, more weight was put onto the carcass during the ZH feeding period which, was observed through an increase in dressing percent. Little information is available

regarding the weight of non-car carcass components of cattle fed BAAs. Comparatively, Avendaño-Reyes et al., (2006) looked at the effects of feeding RH and ZH. Feeding ZH increased REA when compared to control while RH did not. An overall increase in dressing percent was seen with both RH and ZH when compared to control cattle. The author also reported increased Warner Bratzler Shear force in strip loin steaks from cattle fed ZH and RH when compared to control. An increase in muscle, from ZH fed cattle, is reported to be due to hypertrophy rather than hyperplasia. Kellermeier et al. (2009) reported hypertrophy of *Longissimus dorsi* muscle fibers from cattle fed ZH, with an additive effect reported with cattle fed ZH fed with an estradiol-trenbolone acetate implant. Generally, an increase in muscle fiber diameter (hypertrophy) will result in tougher meat. Rathmann et al. (2009) reported that an increase in Warner Bratzler Shear force was likely due to the swelling of the muscle fiber (hypertrophy), this was evident because of the increase in myosin heavy chain proteins rather than a change in the protease enzyme activity within the muscle. Along with tenderness, evaluation of color is also a key aspect for determining meat quality.

Meat color has been studied very closely when feeding BAAs. Avendano-Reyes et al. (2006) reported no difference in lean color with the feeding of ZH and RH when compared to control. However, Hilton et al. (2009) reported that feeding ZH for 30 days resulted in loin eye muscle color that was a brighter cherry red color than the control. The author went on to state that ZH might in fact reduce the amount of metmyoglobin resulting in an improved beef color. VanOverbeke et al. (2009) reported a slight change in color stability with sirloin packaged in modified atmosphere packaging for cattle fed ZH for 20 to 40 days. It was suggested that the feeding of ZH for 20 to 30 days will

result in the brighter, more red sirloin steaks. Rogers et al. (2010) reported no difference in color or purchase preference with consumer panelists for beef cattle or calf-fed Holstein steers fed ZH for 0, 20, 30 or 40 d. It is suggested that with the feeding of ZH for 20-30 d sirloin steaks will have a brighter and more red color when packages in high-oxygen modified atmosphere packaging.

Implants

Hormonal implants have been used in the animal agriculture industry for over 60 years. Typically the hormonal implant consists of a mixture of steroidal hormones including Estrogen (E2), Testosterone or Progesterone in the natural form and synthetic hormones, melengestrol acetate, and trenbolone Acetate (TBA), or zeranol (Dunshea et al., 2005). Implants are placed in the base of the ear allowing slow break down and absorption of the hormones. There are many different combinations of the hormonal implant. This is to provide an array of variety for the different species and also to provide specific hormones for different stages of development.

Androgenic and estrogenic steroids have been shown to significantly increase feed efficiency, increase rate of gain, and increase muscle growth in feedlot cattle. Cattle have shown to have improved feed efficiency as well as rate of gain 15-20% with implanted steers when compared to non-implanted steers (Johnson et al., 1996a; Pampusch et al., 2008; Schanbacher, 1984). A combination of TBA, and E2 implants have been shown to amplify the observed effects including; feed efficiency, rate of gain, and muscle growth in cattle (Bruns et al., 2005; Eversole et al., 1989).

A study conducted by Schanbacher (1984) showed a 25.8% increase in ADG additionally Johnson et al. (1996a) found an increase of 14-25% with the use of TBA-E₂ implants. In a different study, Johnson et al. (1996b) showed an increase in carcass protein deposition with the use of TBA-E₂. It has been suggested that calf-fed Holstein steers do not perform as well on TBA-E₂ implants as beef cattle. This may be due to the fact that Holstein cattle are typically lighter muscled animals than beef cattle and respond very well to increases in androgenic hormones. The use of TBA-E₂ implants in calf-fed Holstein steers could eventually provide a means of avoiding penalties for rib eyes less than 9 square inches (Anderson, 1991). With the use of TBA-E₂ implants cattle producers will be able to avoid discounts from the packer.

TBA-E₂ implants may affect marbling disposition which could ultimately affect the USDA Quality Grade. A study done by Bruns et al. (2005) showed that the use of TBA-E₂ implants had an adverse effect on the development of marbling in the twelfth rib Longissimus muscle. Oppositely, Johnson et al. (1996a) observed no effect on carcass fat or marbling with steers implanted with TBA-E₂. If there is in fact a reduction in the amount of marbling with the use of TBA-E₂ implants, there could be an additive effect when combining the feeding of BAAs with the use of TBA-E₂ implants in reducing total body fat and ultimately the amount of marbling.

Carcass Characteristics

Beef carcass characteristics are used to evaluate the quality and cutability of the beef carcasses being slaughtered today (USDA, 1997). There are many carcass attributes evaluated in determining how palatable the meat from a specific carcass is expected to be

for the consumer. By evaluating the carcass attributes the United States Department of Agriculture (USDA) has set up standard in order to sort carcasses into different categories to provide premiums to producer of meat products that will be more palatable. There are two categories of USDA grading standards, quality grading and yield grading (USDA, 1997). There are other carcass attributes that may affect the consumer's acceptance of the meat products presented to them in a grocery store that may or may not have an actual effect on the eating experience. Lean color for example; if the lean color of the beef product in a grocery store is different a consumer may switch to some other protein.

Lean Color

Lean color progressively changes for steers, heifers and cows as maturity advances. Younger cattle have pinkish grayish lean color, and with age, the lean will change to a dark red color (Hale et. al., 2010). Lean color is assessed by the USDA in the Longissimus *dorsi* muscle between the twelfth and thirteenth rib. A difference in color should only be associated with changes in maturity. Lean color is not intended to account for dark-cutting beef, which is associated with long term stress and the depletion of the glycogen stored in the muscle cells prior to slaughter, resulting in elevated meat pH (USDA, 1997). Lean color is generally assessed using a 9-point scale. A color score of 1 represents a very dark red to brown color and a score of 9 represents a very desirable bright cherry red color (Shackelford et al., 1992).

Lean color and appearance at the retail level have a significant influence on consumer purchase, based on perceived quality of meat products (Carpenter et al., 2001). If the industry is feeding cattle substances that have adverse effect on beef color at the

retail establishment it will have an effect on what the consumer will ultimately buy as their protein portion (Rogers et al., 2010). Consumers have a purchase preference when it comes to lean color and packaging type at the retail establishment, but when consumers in a blind taste test ate meat with differing lean color, there was no taste difference observed. This suggests that lean color and packaging type do not have an effect on taste preference of beef (Carpenter et al., 2001).

Preliminary Yield Grade

The preliminary yield grade (PYG) is a measurement of the subcutaneous fat thickness over the *Longissimus dorsi* (LD) muscle between the twelfth and thirteenth rib. Preliminary yield grade is measured perpendicular to the outside surface, three-fourths of the way down the LD from the chine bone. The starting PYG is 2.00, for every 0.1 inches of subcutaneous fat, the PYG value is increased by 0.25 (Hale et al., 2010). The PYG can be adjusted if the amount of subcutaneous fat thickness over the LD is not representative of the fat across the entire carcass, with special attention to the brisket, chuck, round, cod or udder fat, and flank. If a carcass is fatter over these areas the adjusted preliminary yield grade (APYG) should be increased from the PYG in order to represent the increase in fat. Conversely if the amount of fat is lower in these areas the APYG should be decreased in order to represent the decrease in fat (USDA, 1997). Once the PYG is calculated, three other carcass attributes are taken into account including; KPH fat %, REA and HCW in order to determine a USDA Yield Grade (YG).

KPH Fat %

The weight estimation of kidney, pelvic, and heart (KPH) fat relative to the weight of the hot carcass is used in determining the yield grade. The amount of KPH fat used for the USDA YG calculation is 3.5%. For every 0.5% above or below the standard KPH%, the PYG is increased or decreased 0.1 (Hale et al., 2010). The majority of the KPH fat is found in the loin and round on the carcass. Additionally, there is also a small amount on the chuck and brisket, because this fat is removed for fabrication of the carcass, the amount of it will affect the yield of a carcass (USDA, 1997).

Hot Carcass Weight

Hot Carcass Weight (HCW) is also use in the determination of the USDA Yield Grade. The HCW is the weight of the carcass directly after slaughter, prior to chilling. The carcass weight used for the yield grade equation is 600 lbs (Hale et al., 2010). For each 25 lbs increase in HCW 0.1 is added to the YG, and for every 25 lbs decrease in HCW 0.1 is subtracted from the PYG. As hot carcass weight increases the cutability (the amount of lean relative to bone and fat) goes down, therefore the yield grade is increased (USDA, 2007).

Rib Eye Area

Rib Eye Area (REA) is measured over the LD muscle between the 12th and 13th rib. REA is directly correlated with the amount of muscling in a carcass. The larger the REA, the more muscle a carcass will have. As REA is representative of the extent of muscling, an increase in REA will in turn decrease the yield grade, conversely, a decrease in REA will increase the yield grade. Generally the REA is evaluated visually but it can

be evaluated with a REA grid (USDA, 2007). The average REA is 11.0 in², this is also the starting REA used in the USDA Yield Grade equation. For every 1 in² increase in the REA the PYG has 0.33 subtracted from it and for every 1 in² decrease in REA the PYG has 0.33 added to it. Recent research by Lawrence et al. (2008) suggests that the model for REA in relation to HCW has changed in the past 50 year. It is the author's belief that the cattle that the industry is producing today do not correctly match the model that the USDA grader is basing their Yield grade designations to. If the linear relationship of REA to HCW was corrected to the quadratic relationship that the author suggests, it might increase values of the large animals that the industry is slaughtering today. Furthermore, Belk et al. (1998) suggests there may be some technologies available which might aid in the assignment of the USDA yield grade by the grader. If these technologies could calculate the HCW, REA, and KPH percent, then all the grader has to do is assign the APYG that a computer calculated the YG down to the tenth. Using this type of technology there would be less room for human error because a computer is typically much more consistent.

Maturity

The maturity of a carcass is evaluated using two parts of the beef carcass, bone and lean; specifically the size, shape, ossification of the bone and the color and texture of the lean. The vertebral column is the primary location to determine the physiological maturity of beef carcasses for cattle to be graded for steer, heifers, and cows because it is more reliable than color which can be influenced by postmortem factors. There is a posterior-anterior progression of ossification along the vertebral column. Ossification is the conversion of cartilage to bone, as an animal's aged ossification is first observable at

the sacral vertebrae and moves forward, cranially, along the vertebral column through the lumbar and thoracic vertebrae (Hale et al., 2010). Lean color and texture are also used as an indicator of physiological maturity. Lean maturity is assessed within the LD muscle between the twelfth and thirteenth rib. The LD muscle of very young animals will be very fine in texture and color will be grayish red. As an animal matures the lean color will change to red, and progressively darken with age. Older beef animals will have very dark to purplish red lean color as well as a coarse texture in the LD muscle. When dark-cutting beef occurs, emphasis is placed on the skeleton to determine maturity because the color change will through of the lean maturity assessment (USDA, 2007). Maturity scores range from A to E; A maturity designating the youngest animals, from 9-30 months of age, and E maturity designating the oldest animals, being greater than 96 months of age (Hale et al., 2010).

Warner Bratzler Shear

Meat tenderness is one of the most important aspects associated with a consumer's eating experience (Kanawa et al., 2002). There is a strong correlation between beef tenderness and pricing, more tender cuts of meat are more expensive. Oppositely, less tender cuts of meat tend to be cheaper (Shackelford et al., 1992). This phenomenon is apparent when considering the *psaos major* muscle also called to tenderloin, while it has little fat it is one of the most expensive cuts. This is because it is the tenderest muscle in the beef carcass. One of the tools used to evaluate tenderness is the Warner Bratzler Shear (WBS). The WBS measures peak shear force necessary to shear through a one half inch (1.27 cm) core sample of meat (Leheska et al., 2009). The effect on meat tenderness has been studied in significant detail for the feeding of BAAs

to cattle. In a review of the literature on BAAs, Dikeman (2007) reported that there is a decrease in tenderness when feeding BAAs to cattle and that the tenderness decrease varied with different beta adrenergic agonists.

Kellermeier et al. (2009) showed that while feeding ZH, to cattle implanted with estrogen-trenbolone acetate, the strip loin steaks had shear values 59-70% higher when compared to control for all aging periods: 7, 14, and 21 days. Furthermore, Hilton et al. (2009) showed an increase in toughness with ZH fed cattle when compared to a control with only 7 days aging, while 14 and 21 day aged steaks showed no significant difference. Holmer et al. (2009) showed an increase in toughness with ZH fed cattle that were aged 7, 14, and 21 days and even though the steaks from ZH fed cattle were tougher, the meat actually had a larger amount of tenderization. When feeding ZH there was an increase in toughness from steaks that are aged for a short period of time. However, when meat from ZH fed cattle were allowed to age, there was a greater reduction in toughness, making the effect of increased WBS less significant (Hilton et al., 2009). This may be due to a change in the enzymatic activity occurring post mortem with the ZH fed cattle.

The enzyme system believed responsible for postmortem proteolytic degradation of meat and ultimately the increase in tenderness is the Calpain system (Koohmarie and Geesink, 2006). The specific enzymes involved in tenderization are: μ -calpain, m-calpain, and calpastatin. Calpains are a family of calcium-dependant, proteolytic enzymes that are present in cattle as well as many other animals (Ohno et al., 1984). The μ -calpain and m-calpain are responsible for the breakdown of myofibular proteins such as desmin while calpastatin inhibits the two enzymes (Thomson et al., 1996). It is

believed that with the feeding of BAAs the amount of the specific enzymes are changed causing an increase in the enzyme calpastatin, which is an enzyme that decreases enzymatic turnover. Alternatively Rathmann et al. (2009) observed no changes in enzymatic activity with ZH fed cattle when compared to control. The author suggested that the difference in WBS from cattle fed ZH may be from an increase in myosin heavy chain proteins which correlates with the observed hypertrophy of muscling.

Kanawa et al. (2002) suggested that the Calpain system, more specifically μ -calpain, could not be responsible for the postmortem tenderization of meat. The author states that the pH of meat during the aging process, 5.4-5.8, is too low for μ -calpain to be activated. Moreover, the calcium level in meat is too low to activate μ -calpain, which is a calcium dependant enzyme. The author goes on to suggest that calcium alone is responsible for the breakdown and/or weakening of the myofibular protein desmin because the calcium ion is about 2000 times higher concentration in meat than in the physiological state in muscle of live animals. Alternatively, in a review of the literature conducted by Koohmarie and Geesink (2006) specifically discussing the effects of the Calpain system on the postmortem tenderization of meat. The authors discussed that the calpain system and more specifically the enzyme μ -calpain is largely responsible for the postmortem tenderization of meat. M-calpain was shown to be stable within the muscle cells for a prolonged period of time, longer than μ -calpain, while tenderization of muscle did not continue. This led to conducting an experiment with μ -calpain knock-out mice which showed that once μ -calpain was knocked out the postmortem proteolysis was largely inhibited.

Introduction

The animal agriculture industry is constantly trying to produce a more sustainable animal by finding methods which increase productivity while reducing the total inputs required. Large improvements have been accomplished by genetic selection and a better understanding of the animal's nutritional needs (Dunshea et al., 2005). Producers are using technologies that utilize the natural metabolic pathways in order to reach these goals. Some of the technologies used are anabolic steroid implants and feeding β -adrenergic agonists (BAA). By utilizing these metabolic modifiers a producer is capable of providing animals to the market place at a faster rate and lower cost.

The use of β -adrenergic agonists, like Zilpaterol hydrochloride (ZH), in beef cattle has been studied for over twenty years. Zilpaterol hydrochloride has been reported to increase feed to gain ratio, average daily gain, and hot carcass weight, while having little effect on lean color, maturity score, and visceral fat percent; ZH also been shown to have an adverse effect on tenderness (Avendaño-Reyes et al., 2006; Elam et al., 2009; Mersmann, 1998). Zilpaterol hydrochloride was approved by the Federal Drug Administration (FDA) to be fed to cattle in the United States in 2006. Since then there has been interest in determining the effects of ZH in beef cattle. More recently there has been a large amount of research in calf-fed Holstein steers as they have been shown to perform very well when fed ZH (Beckett et al., 2009). Zilpaterol hydrochloride is approved to be fed for 20 to 40 days and requires a minimum 3 d withdrawal period due to concerns of residual BAA in the liver. This mandatory withdrawal period requires producers to schedule the feeding time and withdrawal period to make sure they meet the FDA requirement. There has been little data reported concerning producer that are

unable to meet the scheduled shipping date to the slaughter facility. If the cattle should be put back onto the BAA so they do not lose the effect of ZH or should the producer hold the cattle until the next shipping opportunity. Recently, Shook et al. (2009) evaluated the effect of a prolonged withdrawal period in beef cattle and found there to be little difference with a 3 d to 10 d withdrawal period, but as the withdrawal period increased, the ZH effect to the carcass decreased.

The objective of this research was to evaluate the effect of feeding ZH for 20 days to calf-fed Holstein steers on carcass characteristics and tenderness. Also evaluate the effect of a 3 day antemortem withdrawal period compared to a 10 day antemortem withdrawal period on carcass characteristics and tenderness.

Materials and Methods

Calf-fed Holstein steers (approximately 125 kg) were purchased from commercial calf ranches and transported to a commercial feedlot. Cattle were fed a high energy diet for a minimum of 240 days prior to the start of the experiment. Treatments consisted of cattle fed ZH for 20 days with a 3 (Z3) or 10 (Z10) day withdrawal period antemortem and a control for both the 3 (C3) and 10 (C10) day withdrawal. The 10 day withdrawal cattle were started on feed 7 days earlier than the 3 day withdrawal cattle. Harvest dates were selected on pen expected body weight (BW) and visual evaluation of finish. Each experimental group was harvested over a two day period at a commercial USDA inspected slaughter facility.

Cattle selection

Calf-fed Holstein steers (N=2293) were selected for this feeding trial conducted over 2 replications. From the original 2400 steers, 2293 cattle were used in the experiment. Cattle were removed from the trial for size nonconformity or health concerns. Cattle were blocked by source and randomly assigned to one of four treatment groups (Z3 = 568, Z10 = 573, C3 = 573, C10 = 579). Cattle from each treatment group were randomly assigned to pen, there were 6 pens per treatment with a total of 24 pens for the experiment (12 pens per replicate). Cattle were vaccinated and dewormed following the feedlot's established protocol. Steers received a Synovex S (200 mg progesterone and 20 mg estradiol benzoate; Ford Dodge Animal Health, Overland Park, KS) implant prior to the start of the experiment. Cattle were processed following the feedlots established protocol for final sort where they received a terminal implant (Revalor IS; 80 mg trenbolone acetate and mg estradiol; Intervet/Schering-Plough Animal Health, Desoto, KS).

ZH Feeding

Cattle were fed twice daily by feed truck following established feedlot protocol. Feed was milled daily in a continuous feed mill. Residual feed was evaluated each morning and the amount of feed offered was increased or decreased accordingly. Feed was maintained on an *ad libitum* basis and carry over was kept at a minimum. Zilpaterol hydrochloride was added to the original diet for 20 d at a rate of 8.3 mg/kg on a 100% DM basis. At the beginning of ZH feeding, the non ZH feed was removed, bunks were

swept and the ZH diet was provided. On the final day of the ZH diet, bunks were swept and cattle were returned back to the control diet.

Carcass Evaluation and Grading

The carcasses were electrically stimulated post-exsanguination, and prior to hide removal. Carcasses were chilled for a minimum of 40 hours prior to carcass evaluation and grading. Carcasses were ribbed between the 12th and 13th rib. After ribbing, chromatography paper was applied to collect an outline of the Longissimus *dorsi* muscle. Rib-eye area was determined using the Meatscan Image Analyzer software (AEW Consulting, Lincoln, NE). Longissimus *dorsi* muscle was allowed to bloom for approximately 7 minutes prior to visual evaluation. Carcasses were evaluated by trained personnel to determine marbling score (MS), lean and skeletal maturity, 12th rib fat thickness, kidney pelvic and heart (KPH) fat %, lean color, and the USDA assigned quality grade was recorded. Preliminary yield grade (PYG) was determined using the 12th rib back fat thickness and adjusted for body fat (APYG). The calculated yield grade was determined using: APYG, KPH fat %, REA, and HCW (USDA, 1997).

Warner Bratzler Shear

Carcasses were randomly selected (n=60) using a random number generator, from all 4 treatment groups. Strip loins (International Meat Purchase Specifications # 180) were removed on the fabrication floor; individual identification was maintained throughout the fabrication process and vacuum packaged. Strip loins were transported via refrigerated vehicle to California Polytechnic State University for tenderness evaluation. Strip Loins (IMPS # 180) had 4 (2.54 cm) steaks cut from the cranial end. The first steak

was set aside and was not used for Warner Bratzler Shear (WBS); it was considered a face cut in order to maintain consistency for the following steaks. Steaks 2, 3, and 4 were randomly assigned an aging period of either; 7, 14, or 21 days. Each steak was vacuum packaged and aged in a cooler (2° C) for its respective aging periods, blast frozen (-28° C for 24 h), then stored in the freezer (-23° C) until time of WBS analysis.

Prior to WBS analysis steaks were removed from the freezer and placed in the cooler for 24 h. Thawed steaks (>0° C) were weighed, had a thermocouple probe placed into geometric center of steak, cooked on a George Foreman Grill Machine (Model: GRP99 B) at 204° C until internal temperature reached at least 71.0° C. Internal temperature was recorded with an Omega data logger thermometer (HH309). Upon reaching 71.0° C steaks were weighed and then placed into cooler to chill for 24 h.

Warner Bratzler Shear analysis was conducted on a Warner Bratzler Meat Shear with Basic Force Gauge (BFG 500N). Steaks were removed from the cooler and 6 (1.27 cm) core samples were taken following the longitudinal orientation of the muscle fiber. Core samples were inspected and any cores with connective tissue or large pieces of fat were not evaluated. Peak shear force was recorded. Mean peak shear forces was calculated giving the WBS value for each steak.

Statistical analysis was conducted using the PROC GLM (SAS Ints. Inc. Cary, NC) for the carcass characteristics where the experimental unit was considered pen. Comparisons consisted of C3 to Z3, C10 to Z10, and Z3 to Z10. Least squares means were reported and PDIFF's were considered significant when $P < 0.05$. Statistical analysis was conducted using the PROC MIXED (SAS ints. Inc. Cary, NC) for Warner

Bratzler shear analysis where the experimental unit was strip loin and the pen was considered a random factor. Least squares means were reported for orthogonal contrasts and PDIFF's were considered significant when $P < 0.05$.

Results

Carcass Characteristics

Carcass data are presented in Table 1 and 2. No ZH by withdrawal period interactions were observed for any parameters evaluated ($P > 0.05$), therefore only main effects will be discussed between each withdrawal group. Rib-eye area was increased 3.8 cm² from Z3 cattle ($P < 0.01$) when compared C3, and 5.9 cm² from Z10 cattle ($P < 0.01$) when compared to C10. There was no significant difference in REA between ZH fed 3 and 10 day withdrawal periods ($P = 0.4719$). A trend was observed for Z10 to have an increase HCW of 6.8 kg when compared to C10 ($P = 0.06$). There was no significant difference with HCW of Z3 cattle compared to control ($P = 0.3763$) comparatively. KPH % and APYG did not differ significantly between ZH for both withdrawal periods compared to control. There was a significant decrease in calculated yield grade from cattle fed ZH for both withdrawal groups compared to control ($P < 0.05$). The reduction in yield grade is likely due to the significant increase of REA. There was no difference in KPH, APYG, or calculated yield grade from ZH fed cattle with a 3 day withdrawal period compared to 10 day withdrawal period ($P > 0.05$). Marbling score, Lean maturity and bone maturity were unaffected with the feeding of ZH compared to control for either of the withdrawal periods ($P > 0.05$). There was no difference between Z3 and Z10 for any carcass characteristic observed ($P > 0.05$).

Tenderness

Warner Bratzler Shear data are presented in Figures 1 and 2. There were 3-way interactions observed for; ZH feeding, withdrawal period and aging period. Therefore only the 3-way interactions were analyzed. Due to the interaction the data is only reported for; within withdrawal groups (Z3 vs. C3 or Z10 vs. C10) or between withdrawal groups (Z3 vs. Z10 or C3 vs. C10). There was a 1.61 kg increase in shear force values for Select 7 d aged Z10 steaks compared to USDA Select 7 d aged C10 steaks ($P<0.05$). Additionally, there was a 0.49 kg increase in shear value for USDA Select 14 d aged Z3 steaks compared to USDA Select 14 d aged C3 steaks ($P<0.05$) and a 0.63 kg increase in shear value for USDA Select 14 d Z10 steaks compared to USDA Select 14 d aged C10 steaks ($P<0.05$). Similarly, there was a 0.91 and 1.24 kg increase for USDA Choice 7 d aged Z3 and Z10 steaks compared to USDA Choice 7 d aged C3 and C10 steaks ($P<0.05$). Also, there was a 0.71 and 0.50 increase in shear value for USDA Choice 14 d aged Z3 and Z10 steaks compared to USDA Choice 14 d aged C3 and C10 steaks ($P<0.05$). Alternatively, there was no difference in USDA Select steaks aged 21 d from any of the treatment groups or USDA Choice steaks aged 21 d from the Z3 treatment group ($P>0.05$). There was an increase in the USDA Choice Z10 21 d aged steaks of 0.87 kg respectively ($P<0.05$). There were no significant differences observed from the Z3 withdrawal group compared to the Z10 withdrawal group for any of the aging periods for both USDA Choice and Select steaks. Interestingly, the shear value (2.26 kg) for the USDA Choice 21 d aged C10 treatment was significantly lower than any of the 21 d aged treatment groups. Therefore, the Choice 21 d aged C3 treatment had (0.53 kg) higher shear force than the C10 treatment ($P<0.05$).

Discussion

Carcass Characteristics

There was no effect of withdrawal period on any carcass characteristic evaluated or tenderness for cattle fed ZH for 20 days. Zilpaterol HCl did increase rib eye area in cattle when compared to control (Mersmann, 1998). The current study showed an increase of 3.8 cm² to 5.9 cm² depending on withdrawal period. These findings were consistent with Beckett et al. (2009) that feeding ZH for 20, 30, or 40 days to calf-fed Holsteins steers resulted in an increase in REA of 5.1 cm², 8.9 cm², and 8.5 cm² respectively. Similarly, studies conducted by Avendaño-Reyes et al. (2006) and Kellermeier et al. (2009) found that with the feeding of ZH for 30 days there was an increase in REA of 8.48 cm² and 11.15 cm².

There tended to be an increased HCW from cattle fed Z10 cattle (P=0.058) while there was no effect for the Z3 cattle. Other research has seen an increase in HCW when feeding ZH from 11.6 kg to 21.9 kg respectively (Avendaño-Reyes et al., 2006; Beckett et al., 2009; Kellermeier et al., 2009). There was no difference in KPH fat % or APYG. This coincides with many studies showing little to no difference in KPH fat % or subcutaneous back fat thickness for cattle fed ZH compared to control (Avendaño-Reyes et al., 2006; Beckett et al., 2009). It is believed that the sole contributor to the reduction of the yield grade for ZH fed cattle is due to the large increase in REA since it was the only part of the USDA Yield grade equation that had a significant change.

The feeding of ZH had little effect on carcass fat with the current study. Possibly, ZH does not have an effect on reducing fat on cattle it just has an effect of increased lean

depositions. These findings are supported by Leheska et al. (2009) which observed and increase in total carcass protein for ZH fed cattle while carcass fat was not affected. Similarly, Hilton et al. (2009) observed and increase in protein to fat ratio, with an overall increase in protein and decrease in fat. Furthermore, it was observed that ZH had little effect on Calpastatin, meaning that there was more of an effect on the accretion of protein rather than a reduction in proteolysis. Marbling score was unaffected in the current study ($P>0.05$). Beckett et al. (2009) reported that there tended to be a decrease in MS from calf-fed Holsteins fed ZH for 20 d, while there was a significant decrease for cattle fed ZH for 30 and 40 d. These findings were supported by Kellermeier et al. (2009) were feeding ZH for 30 d to calf-fed Holstein steers significantly decreased MS. Interestingly, both Beckett et al. (2009) and Kellermeier et al. (2009) observed a significant decrease in marbling, opposite from the current study, meanwhile there was no change in PYG, APYG, or KPH fat % which is very similar to the current study. These authors also reported a larger increase in REA compared to the current study. If ZH does not decrease fat, and only increases lean, there may be a dilution effect of the marbling in the larger Longissimus muscle. That is the Longissimus muscle is getting larger and the amount of intramuscular fat is not changing so there appears to be less overall marbling compared to the amount of lean. Possibly the marbling score was not decreased for the current study because the REA was not increased enough to detect a change or dilution in marbling.

Tenderness

The current study observed that ZH fed cattle had increased WBS values compared to control. The increased WBS of steaks from ZH fed cattle seemed to decrease as aging period progressively increased. Warner Bratzler shear was increased

for ZH fed cattle, WBS is also dependent on the amount of days that ZH is fed. Warner Bratzler shear was reduced with increased days aged from cattle fed ZH (Avendaño-Reyes et al., 2006; Beckett et al., 2009; Brooks et al., 2009; Hilton et al., 2009; Holmer et al., 2009; Leheska et al., 2009). According to Huffman et al. (1996) who evaluated consumer acceptance of strip loins steaks, in order to have a 98% consumer acceptance the WBS values need to be less than 4.1 kg. The average WBS for steaks aged 14 or 21 d from ZH fed cattle was 3.44-3.95 or 3.07-3.16 kg. This suggests that allowing meat from cattle fed ZH to age for a minimum of 14 d should result in meat that is acceptable to the consumer.

Conclusion

There was no difference between a 3 d or 10 d antemortem withdrawal period for ZH fed cattle for any carcass characteristic, or WBS for USDA Choice and Select steaks aged 7, 14, or 21 days. There was an increase in REA for ZH fed cattle when compared to control and there was an overall decrease in USDA Yield Grade for ZH fed cattle compared to control. There were no changes for any other carcass characteristic. The increase in lean and no change in fat is different than what has been reported for other BAA's, and more research should be conducted looking at this phenomenon. Potentially ZH does not have an effect on fat and reported reductions may be due to a dilution effect from an increase in the total amount of lean. Feeding ZH did result in an increase in WBS values when compared to control for the early aging periods but as the aging period

increase there was little to no difference. If calf-fed Holstein steers are held off ZH for 3 to 10 days the effects of feeding ZH will not change.

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Table 1. The effect of feeding Zilpaterol hydrochloride for 0 or 20 days with a withdrawal time of 3 or 10 days on carcass characteristics.

Item	3 Day Withdrawal					10 Day Withdrawal				
	0	SEM	20	SEM	<i>P</i>	0	SEM	20	SEM	<i>P</i>
Adjusted Preliminary Yield										
Grade	2.8	0.1	2.8	0.1	0.72	2.8	<0.1	2.8	<0.1	0.59
Hot Carcass Weight (kg)	350.4	2.6	354	3	0.38	353.5	2.2	360.3	2.3	0.06
Kidney Pelvic Heart Fat%	3.2	<0.1	3.2	<0.1	0.66	3.2	<0.1	3.2	<0.1	0.14
Rib Eye Area (cm ²)	75.9	0.9	79.7	0.6	<0.01	75	0.6	80.4	0.7	<0.01
Marbling Score	425	6.9	424.5	7.4	0.95	440.4	3.3	427.4	10.3	0.26
Lean Color	4.8	0.1	5	0.1	0.34	5.2	0.1	5.2	0.2	0.99
Bone Maturity	31.7	5.2	34.1	6.2	0.78	35.3	5.7	36.6	7.7	0.89
Lean Maturity	50.4	0.8	49.2	0.7	0.22	50.2	0.8	50	0.6	0.84
USDA Yield Grade	3.2	0.1	3	0.1	0.02	3.2	0.04	3	0.08	0.05

0- Control cattle fed no Zilpaterol Hydrochloride

20- Treatment cattle fed Zilpaterol Hydrochloride (8.3 mg/kg) for 20 days

SEM- Standard error of the mean

Table 2. The effect of feeding Zilpaterol hydrochloride for 20 days with a withdrawal time of 3 or 10 days on carcass characteristics.

Item	3 day	SEM	10 day	SEM	<i>P</i>
Adjusted Preliminary Yield					
Grade	2.8	<0.1	2.8	<0.1	0.64
Hot Carcass Weight (kg)	354	3	360.3	2.3	0.13
Kidney Pelvic and Heart Fat %	3.2	<0.1	3.2	<0.1	0.66
Rib Eye Area (cm ²)	79.7	0.6	80.4	0.7	0.47
Marbling Score	424.5	7.4	427.4	10.3	0.82
Lean Color	5	0.1	5.2	0.2	0.34
Bone Maturity	34.1	6.2	36.6	7.7	0.8
Lean Maturity	49.2	0.7	50	0.6	0.41
USDA Yield Grade	3	0.1	3	<0.1	0.98

SEM- Standard error of the mean

Figure 1: Warner Bratzler Shear (WBS) analysis on USDA Select strip loin steaks from calf-fed Holstein steers fed Zilpaterol hydrochloride (ZH) for 0 or 20 days with a 3 or 10 day withdrawal period antemortem.

xy denotes significant difference between treatment (Z3 vs C3 or Z10 vs C10) for each aging period (7, 14, or 21 days).

ab denotes significant difference within treatments (C3 vs C10 or Z3 vs Z10) for each aging period (7, 14, or 21 days).

Figure 2: Warner Bratzler Shear (WBS) analysis on USDA Choice strip loin steaks from calf-fed Holstein steers fed Zilpaterol hydrochloride (ZH) for 0 or 20 days with a 3 or 10 day withdrawal period antemortem.

xy denotes significant difference between treatment (Z3 vs C3 or Z10 vs C10) for each aging period (7, 14, or 21 days).

ab denotes significant difference within treatments (C3 vs C10 or Z3 vs Z10) for each aging period (7, 14, or 21 days).

Appendix

Cal Poly Study Number: _____

Investigator: _____

Kill Order & Identification Data Collection Form

Recorded By: _____

Date _____

Kill Order	Animal ID	Lot Tag		Kill Order	Animal ID	Lot Tag		Kill Order	Animal ID	Lot Tag
1				26				51		
2				27				52		
3				28				53		
4				29				54		
5				30				55		
6				31				56		
7				32				57		
8				33				58		
9				34				59		
10				35				60		
11				36				61		
12				37				62		
13				38				63		
14				39				64		
15				40				65		
16				41				66		
17				42				67		
18				43				68		
19				44				69		
20				45				70		
21				46				71		
22				47				72		
23				48				73		
24				49				74		
25				50				75		

Note: Animal ID is the eartag number.

Cal Poly Study Number: _____

Investigator: _____

Sequence Number & Hot Carcass Weight (HCW) Form

Recorded By: _____ Date _____

Kill Order	Plant Sequence No.	HCW, lbs.		Kill Order	Plant Sequence No.	HCW, lbs.
1				26		
2				27		
3				28		
4				29		
5				30		
6				31		
7				32		
8				33		
9				34		
10				35		
11				36		
12				37		
13				38		
14				39		
15				40		
16				41		
17				42		
18				43		
19				44		
20				45		
21				46		
22				47		
23				48		
24				49		
25				50		

Cal Poly Study Number: _____

Investigator: _____

PYG, APYG and KPH Data Collection Form

Recorded By: _____ Evaluated By: _____ Date _____

Kill Order	PYG	APYG	KPH		Kill Order	PYG	APYG	KPH
1					26			
2					27			
3					28			
4					29			
5					30			
6					31			
7					32			
8					33			
9					34			
10					35			
11					36			
12					37			
13					38			
14					39			
15					40			
16					41			
17					42			
18					43			
19					44			
20					45			
21					46			
22					47			
23					48			
24					49			
25					50			

PYG = Preliminary Yield Grade; APYG = Adjusted Preliminary Yield Grade; KPH = Kidney, Pelvic, Heart

Cal Poly Study Number: _____

Investigator: _____

Lean and Bone Maturity Data Collection Form

Recorded By: _____ Evaluated By: _____ Date _____

Kill Order	Lean Maturity	Bone Maturity		Kill Order	Lean Maturity	Bone Maturity		Kill Order	Lean Maturity	Bone Maturity
1				26				51		
2				27				52		
3				28				53		
4				29				54		
5				30				55		
6				31				56		
7				32				57		
8				33				58		
9				34				59		
10				35				60		
11				36				61		
12				37				62		
13				38				63		
14				39				64		
15				40				65		
16				41				66		
17				42				67		
18				43				68		
19				44				69		
20				45				70		
21				46				71		
22				47				72		
23				48				73		
24				49				74		
25				50				75		

Cal Poly Study Number: _____

Investigator: _____

Marbling and Color Score Data Collection Form

Recorded By: _____ Evaluated By: _____ Date: _____

Kill Order	Marbling Score	Color Score		Kill Order	Marbling Score	Color Score		Kill Order	Marbling Score	Color Score
1				26				51		
2				27				52		
3				28				53		
4				29				54		
5				30				55		
6				31				56		
7				32				57		
8				33				58		
9				34				59		
10				35				60		
11				36				61		
12				37				62		
13				38				63		
14				39				64		
15				40				65		
16				41				66		
17				42				67		
18				43				68		
19				44				69		
20				45				70		
21				46				71		
22				47				72		
23				48				73		
24				49				74		
25				50				75		

Color Score: 1 = light pink, 2 = pink, 3 = dark pink, 4 = light cherry red, 5 = cherry red, 6 = dark red, 7 = very dark red, 8 = maroon, 9 = dark maroon.

Cal Poly Study Number: _____

Investigator: _____

Stamped USDA Yield & Quality Grades and Carcass Premium/Discounts

Recorded By: _____ Date: _____

Kill Order	Stamped YG	Stamped QG	Premium or Discount	Kill Order	Stamped YG	Stamped QG	Premium or Discount
1				26			
2				27			
3				28			
4				29			
5				30			
6				31			
7				32			
8				33			
9				34			
10				35			
11				36			
12				37			
13				38			
14				39			
15				40			
16				41			
17				42			
18				43			
19				44			
20				45			
21				46			
22				47			
23				48			
24				49			
25				50			

- YG = USDA Yield Grade (1, 2, 3, 4, 5) QG = USDA Quality Grade (NR = No Roll; Se = Select; Ch = Choice; Pr = Prime)
- Bruise trim by primal: Minor (~0.66 lb.), Major (~1.5 lb.), Critical (~3.2 lb.); Round, Loin, Rib, Chuck, Flank, Plate, Brisket
- Dark-Cutter Score: 5 = Not Dark; 4 = 1 to 33 % Dark; 3 = 34 to 66 % Dark; 2 = 67 to 99 % Dark; 1 = 100 % Dark
- Other discounts: Bloodsplash, Callous, 30+, Bullock

Cal Poly Study Number: _____

Investigator: _____

Ribeye Area Data Collection Form

Recorded By: _____

Date: _____

Kill Order	Ribeye Area		Kill Order	Ribeye Area		Kill Order	Ribeye Area		Kill Order	Ribeye Area
1			26			51			76	
2			27			52			77	
3			28			53			78	
4			29			54			79	
5			30			55			80	
6			31			56			81	
7			32			57			82	
8			33			58			83	
9			34			59			84	
10			35			60			85	
11			36			61			86	
12			37			62			87	
13			38			63			88	
14			39			64			89	
15			40			65			90	
16			41			66			91	
17			42			67			92	
18			43			68			93	
19			44			69			94	
20			45			70			95	
21			46			71			96	
22			47			72			97	
23			48			73			98	
24			49			74			99	
25			50			75			100	